REPORT No. 370

EFFECT OF VARIATION OF CHORD AND SPAN OF AILERONS ON HINGE MOMENTS AT SEVERAL ANGLES OF PITCH

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SUMMARY

This report presents the results of an investigation of the hinge moments of ailerons of various chords and spans on two airfoils having the Clark Y and U. S. A. 27 wing sections, supplementing the investigations described in References 1 and 2, of the rolling and yawing moments due to similar ailerons on these two airfoil sections.

The measurements were made at various angles of pitch, but at zero angle of roll and yaw, the wing chord being set at an angle of +4° to the fuselage axis. In the case of the Clark Y airfoil the measurements have been extended to a pitch angle of 40°, using ailerons of span equal to 67 per cent of the wing semispan and chord equal to 20 and 30 per cent of the wing chord.

The work was done in the 10-foot tunnel of the Bureau of Standards on models of 60-inch span and 10-inch chord, having square tips, no taper in plan form or thickness, zero dihedral, and zero sweepback.

INTRODUCTION

This investigation was carried out in cooperation with the aeronautics branch of the Department of Commerce and the National Advisory Committee for Aeronautics, for the purpose of furthering the knowledge of the hinge moments of conventional ailerons on some representative American wing sections. Very little work on the hinge moments of ailerons has been published, the most extensive being that of Irving, Owen, and Hankins. (Reference 3.)

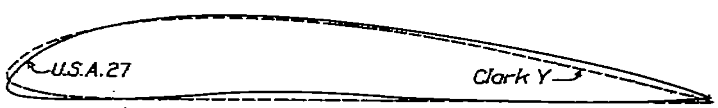
DESCRIPTION OF APPARATUS AND MODELS

A description of the tunnel and models is given in Reference 1, and the profiles and coordinates of the sections are shown in Figure 1.

As it was necessary to modify the hinging of the ailerons from the method used when measuring rolling and yawing moments, it was decided to construct a new set of ailerons rather than adapt the old. Figure 2 shows the scheme adopted.

All the ailerons were mounted on the right wing tip, as this had a rectangular opening 20 inches in span by 3.5 inches in chord cut from the trailing edge. Each aileron had a companion strip or filler block such that the two would fill the space in the wing and conform with the wing section to within ±0.02 inch. A metal end plate, cut to the section used, fastened the filler block to the wing and acted as a bearing plate for the pivot at the outer end of the aileron, while small metal straps sunk into the upper and lower surfaces of the wing and filler block secured the other end of the filler block. The pivot bearing at the inside end of the aileron was carried in a piece of metal sunk into the wing body in the case of ailerons of 20-inch span and into the filler block in the case of ailerons of 10 and 15 inch span. Placing all the ailerons on the same wing tip minimized the effect of twist in the tunnel air flow mentioned in Reference 2.[1]

The pivots were made of steel and threaded through brass blocks set into the ends of the ailerons. By this means end play was done away with and the gap between the inside end of the aileron and the wing body kept small.



% chord		0	1.25	2.5	5.0	7.5	10	15	20	30	40	50	60	70	80	90	95	100
U.S.A.27	Upr.	1.77	3.80	5.07	6.94	8.22	9.19	10.50	11.37	11.97	11.68	10.86	9.54	8.06	6.10	3.89	2.26	0.67
	Lwr.	1.77	0.50	0.36	0.19	0.10	0.02	0.10	0.36	0.93	1.14	0.75	0.26	0.06	0.01	0.12	0.33	0.65
Clark Y	Upr.	3.62	5.38	6.43	7.63	8.79	9.56	10.63	11.32	11.68	11.37	10.49	9.13	7.34	5.21	2.79	1.50	0.12
	Lwr.	3.58	1.86	1.42	0.91	0.55	0.39	0.12	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 1.—Profiles and coordinates of Clark Y and U. S. A. 27 wing sections

A metal sting ending in a small eye was placed in the trailing edge of each aileron 10 inches from the outside end to furnish a point of attachment for the balance and counterweight wires.

Due to difficulties in construction it was necessary to leave a slight gap between the aileron leading edge and the filler block. An effort was made to smooth over the crack while sealing the gap, so as to duplicate

[1] After the completion of the work described in this paper and in References 1 and 2, our attention was directed to some theoretical work described in Reference 4, which indicates that the combined results obtained by summation of tests on a single aileron are not exactly the same as would be obtained by the use of two ailerons because of differences in the lift distribution.

conditions during the rolling and yawing moment tests. Filling the cracks with a hard grease was found to be impractical because of the added friction. A seal of thin sheet rubber over the joint was also tried. When both edges of the rubber were cemented the stretch of the sheet added too much restoring force and when

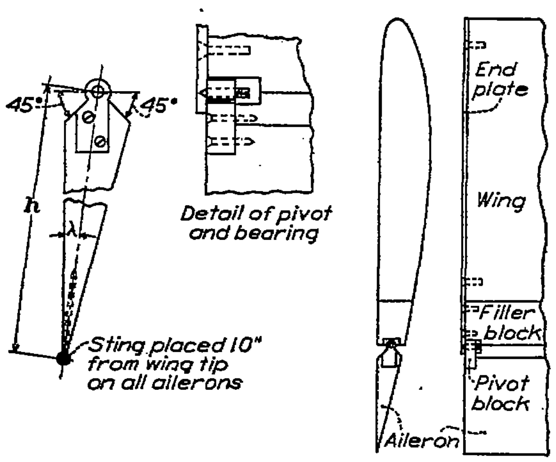


FIGURE 2.—Construction of ailerons for hinge moment measurement

NOTE.—For dimensioned sketch of model see N. A. C. A. Technical Report No. 298.

only one edge was cemented the sheet fluttered excessively. Finally it was decided to keep the gap as small as possible and to seal it with a thin layer of petroleum jelly. This jelly added no discernible friction and made an effective seal. Since previous tests have shown that a crack introduced little or no change as

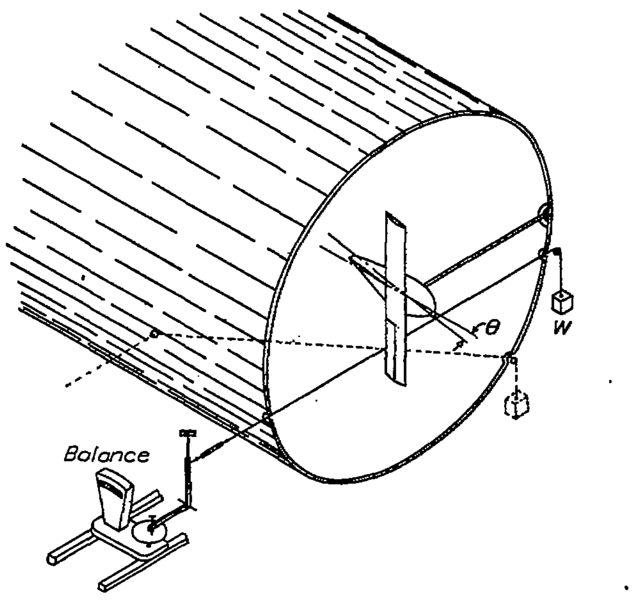


FIGURE 3.—Arrangement for hinge moment measurement

long as the gap was sealed (Reference 3), this method is believed to be satisfactory.

Figure 3 shows the method of mounting the model and of applying the restraining forces. The mode was placed in the tunnel so that the leading edge of the wing was vertical and secured in pitch, roll, and yaw. Wires from the sting led on one side over a pulley to a counterweight and on the other side to a bell crank, through which the forces were transmitted to a balance of the pendulum type. As motion of the balance pan would displace the aileron from its setting, an adjusting screw and pointer were provided to bring the aileron back to the desired position.

For all up-aileron measurements and for down-aileron measurements to an angle of pitch of 20°, the balance and counterweight wires were kept normal to the wind direction. For down-aileron measurements

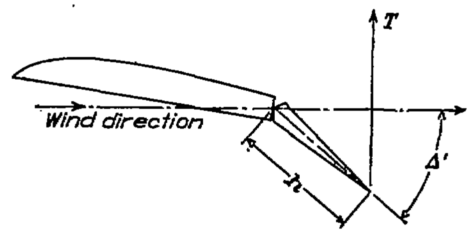


FIGURE 4.—Calculation of hinge moment from balance net T. Hinge moment $= Th \cos \Delta'$

at angles of pitch greater than 20° the balance wire was run downstream at an angle of approximately 35° to the tunnel axis, over a pulley, and out to the bell crank, as indicated by dotted lines in Figure 3. The counterweight wire was carried upstream in a corresponding manner.

METHOD OF OBSERVATION

Observations were made at wind velocities of 40, 58.7, and 80 feet per second (respectively 27.3, 40, and 54.5 miles per hour). Readings were taken at a sufficient number of aileron angles to determine the charac-

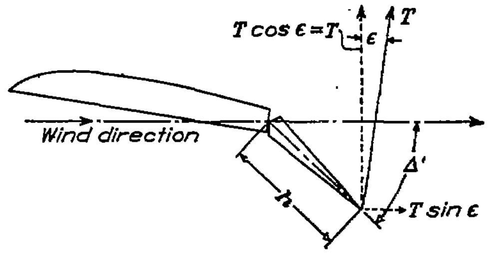


FIGURE 5.—Error due to wire not being vertical. Hinge moment $= Th \cos \epsilon \cos \Delta' + Th \sin \epsilon \sin \Delta'$

teristics of the curves desired. The ailerons were set to the desired angle by means of the turnbuckle shown in Figure 3, and the angle was measured by metal templates applied to the model.

Motion of the balance pan which would allow the aileron to move from its setting was compensated for by an adjusting screw between the end of the bell crank and the balance pan, a pointer and scale being arranged for accuracy of adjustment. By this means the bell-crank arm was kept level, eliminating any error from this source.

REDUCTION OF OBSERVATIONS

The calculation of the hinge moment from the net reading of the balance is made with the aid of Figures 4, 5, 6, and 7. If the wires to the balance and counter-

weight had negligible drag, did not stretch, and remained normal to the wind direction, the hinge moment would equal

$T\,h \cos \Delta'$.

where T = the net reading of the balance.

h = the chord of the aileron measured from the point of attachment of the balance wire to the pivot line of the aileron.

Δ' = the angle between the wind direction and the pivot-to-sting line of the aileron.

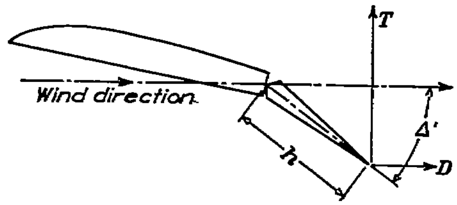


FIGURE 6.—Correction for wire drag, D. Hinge moment $=(T-D \tan \Delta')\,h \cos \Delta'$

If the wire is not normal to the wind direction (fig. 5), the hinge moment is given by the expression

$T\,h \cos \epsilon \cos \Delta' + T\,h \sin \epsilon \sin \Delta'$.

where $90° - \epsilon$ = the angle of the wire to the wind direction.

$T \cos \epsilon$ = the component of the tension in the balance wires normal to the wind direction.

$h \cos \Delta'$ = the effective lever arm of the normal component of the tension.

$T \sin \epsilon$ = the component of the tension in the balance wire parallel to the wind direction.

$h \sin \Delta'$ = the effective lever arm of the parallel component of the tension.

$T\,h \sin \epsilon \sin \Delta'$ and the departure of $\cos \epsilon$ from unity were made negligible by making ϵ small. This was

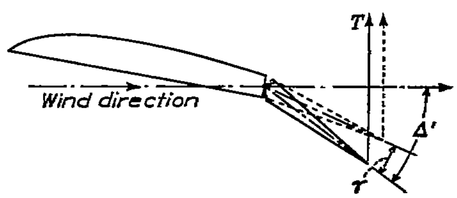


FIGURE 7.—Correction for wire stretch

$\gamma = T\dfrac{\delta}{\cos \Delta'}$ (nearly)

δ = angular deflection caused unit load when aileron is parallel to wind.

accomplished by using a long balance wire and placing the balance so that the deviation, ϵ, with full aileron movement was distributed equally in an upstream and downstream direction.

If the wire drag is not negligible, the true hinge moment (fig. 6) is given by the expression

$(T - D \tan \Delta')\,h \cos \Delta'$.

where D = that part of the wire drag applied to the aileron.

$D\,h \sin \Delta'$ = the moment on the aileron caused by the drag of the wires. This value is expressed as a correction to the measured tension in the above formula.

The wire drag is of sufficient magnitude to be carried through the computations. In computing the part of the wire drag applied to the aileron, the drag is assumed to be uniformly distributed over that part of the wire exposed to the air stream.

The wires will change length, or stretch, with increasing load. The angular deflection (fig. 7) is given with sufficient accuracy by the expression

$$\gamma = T\frac{\delta}{\cos \Delta'}$$

where γ = the angular deflection due to the stretch of the wire.

δ = the angular deflection due to one unit of load when the aileron is parallel to the wind direction.

By using a steel wire of sufficient diameter this deflection was made negligible for the forces encountered in this test.

For the measurement of hinge moments on down-ailerons at pitch angles above 20° it was necessary

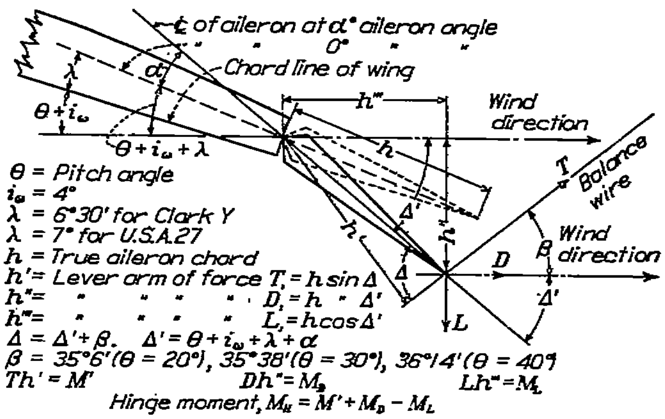


FIGURE 8.—Computation of hinge moments for down aileron at high pitch angles

to run the balance and counterweight wires at an angle of approximately 35° to the wind direction, as shown by the dotted lines in Figure 3. The resolution of the forces is shown in Figure 8. In this case the lift component of the force on the wires must be considered.

The expression for hinge moment is given as

$$M_H = M' + M_D - M_L$$

where M_H = the hinge moment.

M' = the moment due to the net tension in the balance wire.

M_D = the moment due to the drag of the wire.

M_L = the moment due to the lift of the wire.

and $M' = T\,h \sin \Delta$.

$M_D = D\,h \sin \Delta'$.

$M_L = L\,h \cos \Delta'$.

where Δ = the angle between the pivot-to-sting line of the aileron and the balance wire.

Δ' = the angle between the pivot-to-sting line and the wind direction.

D = that part of the wire drag applied to the sting.

L = that part of the wire lift applied to the sting.

Values of the various angles for the set-ups used are given in Figure 8.

All results are reduced to the usual N. A. C. A. form of dimensionless coefficients as given below:

$$C_H = \frac{H}{qcS}$$

where C_H = the absolute hinge moment coefficient for one aileron.

H = the hinge moment in pounds-feet.

q = $1/2\ \rho\ V^2 = 0.001189\ V^2$.

c = wing chord in feet.

S = wing area in square feet (chord length × span).

V = wind speed in feet per second.

ρ = the density of air, i. e., 0.002378 slugs per cubic foot at 15° C. and 760 mm. pressure.

A moment tending to produce clockwise rotation as viewed from the pilot's seat is regarded as positive. All values for a single aileron refer to an aileron on the right wing tip, and the values for the ailerons combined are for the right aileron up and the left aileron down.

RESULTS

HINGE MOMENT COEFFICIENTS FOR A SINGLE AILERON

Figures 9, 11, 17, and 19 show values of hinge moment coefficients for a single aileron plotted against per cent aileron chord of wing chord, and Figures 10, 12, 18, and 20 the values plotted against per cent aileron span of wing semispan. From the figures it can be seen that the hinge moment varies roughly as the square of the chord and as the span. For ailerons of varying chord the rate of increase of hinge moment with increasing chord is slightly greater for the U. S. A. 27 wing section than for the Clark Y, while for ailerons of varying span the reverse is true. In general, the moments are higher for the Clark Y section.

Zero hinge moment does not occur at zero aileron angle, but at some upward angle whose value depends on the angle of pitch, the size of the aileron, and the wing section used. Figures 29 and 30 show this travel of angle for zero moment for two ailerons on the Clark Y section.

HINGE MOMENT COEFFICIENTS FOR COMBINED AILERONS

Figures 13, 15, 21, and 23 show values of combined hinge moment coefficients plotted against aileron angle for ailerons of varying chord, and Figures 14, 16, 22, and 24 show values for ailerons of varying span. From these it is seen that the hinge moment varies roughly as the aileron angle. At zero degrees pitch the slope increases at about 20° and decreases again when the angle is greater than 30°. These points of increase and decrease are not present in all of the curves for 12° pitch, most of the curves being concave downwards.

The combined hinge moments also vary nearly as the square of the chord and as the span, with the rate of increase with increasing chord greater for the U. S. A. 27 wing section, and the rate of increase with increasing span greater for the Clark Y section.

In general, ailerons on the Clark Y section give a greater hinge moment coefficient than on the U. S. A. 27, the difference varying with the pitch angle and the size of aileron used.

VARIATION OF HINGE MOMENT COEFFICIENTS WITH ANGLE OF PITCH

Figures 25, 26, 27, 28, 29, and 30 show the effect of angle of pitch on hinge moments of two ailerons of 20-inch span by 2 and 3 inch chord on the Clark Y wing. Figures 25 and 26 show individual values and Figures 27 and 28 combined values plotted against angle of pitch.

Figures 29 and 30 show individual values of hinge moment coefficient for one aileron at various angles of pitch plotted against aileron angle. The curves are fairly smooth except at high angles of pitch, where the curves drop suddenly in the neighborhood of 32° up-aileron. Beyond 12°, increase of pitch has less effect on the hinge moment.

CONCLUSION

In general, the hinge moment of an aileron varies roughly as the square of the chord and as the span. The Clark Y wing section gave higher hinge moments throughout than did the U. S. A. 27. The rate of increase with increasing chord was higher for the U. S. A. 27, and the rate of increase with increasing span was higher for the Clark Y. An increase of the angle of pitch beyond 12° had comparatively little effect on the hinge moment except at large upward displacements of the aileron, at which the hinge moment dropped abruptly, changing sign in one case.

No conclusions are drawn in this report as to the most efficient aileron, as such conclusions would necessitate a study of the rolling and yawing moments in addition to the hinge moments.

ACKNOWLEDGMENT

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REFERENCES

1. Heald, R. H., and Strother, D. H.: Effect of Variation of Chord and Span of Ailerons on Rolling and Yawing Moments in Level Flight. N. A. C. A. Technical Report No. 298, 1928.
2. Heald, R. H., and Strother, D. H., and Monish, B. H.: Effect of Variation of Chord and Span of Ailerons on Rolling and Yawing Moments at Several Angles of Pitch. N. A. C. A. Technical Report No. 343, 1930.
3. Irving, H. B., and Ower, E., and Hankins, G. A.: An investigation of the Aerodynamic Properties of Wing Ailerons. Part I: The Effect of Variation of Plan Form of Wing Tip, and Span of Ailerons. Aeronautical Research Committee (Great Britain), R. & M. 550, 1918.
4. Hartshorn, A. S.: Theoretical Relationship for a Wing with Unbalanced Ailerons. Aeronautical Research Committee (Great Britain), R. & M. 1259, 1929.

BUREAU OF STANDARDS,
WASHINGTON, D. C., *August 11, 1930.*

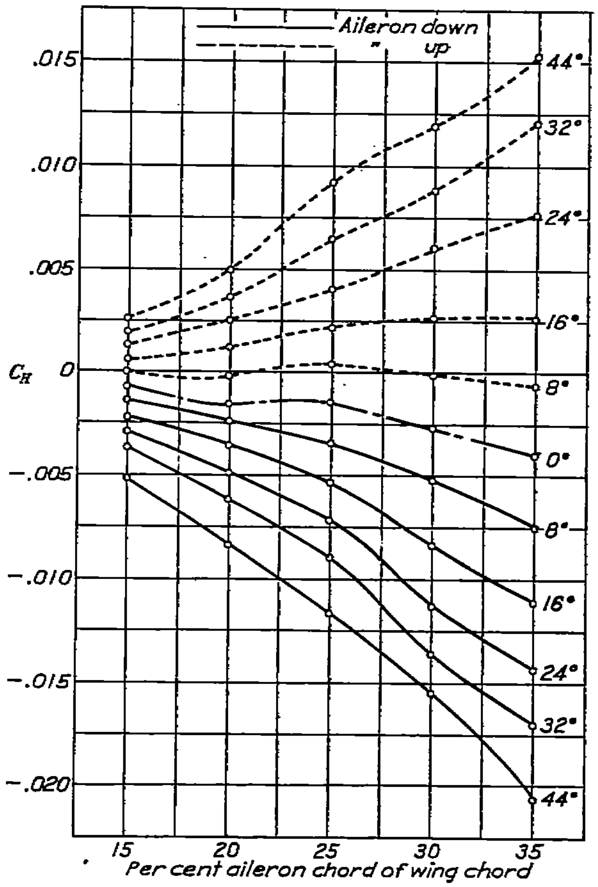

FIGURE 9.—Clark Y wing section. C_H for varying aileron chord—20-inch span (67 per cent of wing semispan). Pitch angle 0°. Roll angle 0°. Yaw angle 0°

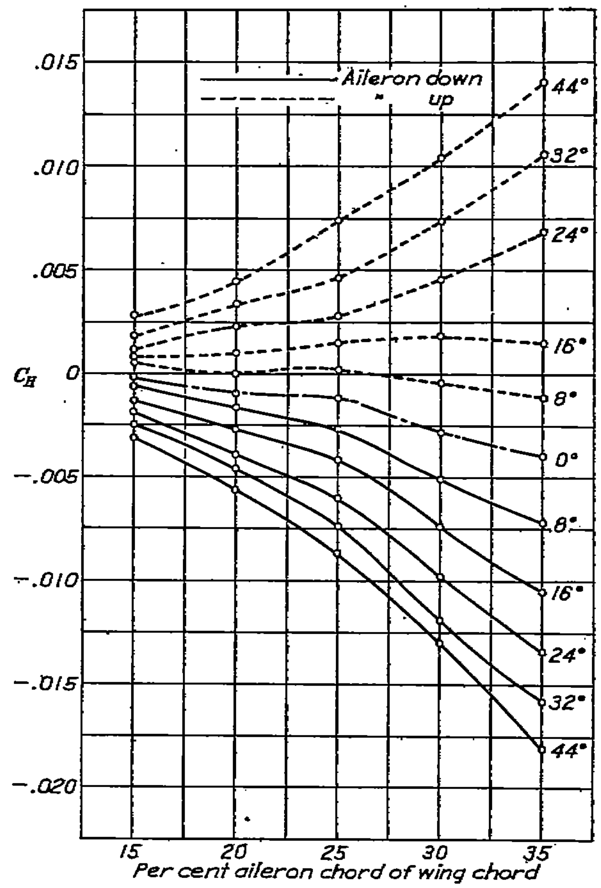

FIGURE 11.—U. S. A. 27 wing section. C_H for varying aileron chord—20-inch span (67 per cent of wing semispan). Pitch angle 0°. Roll angle 0°. Yaw angle 0°

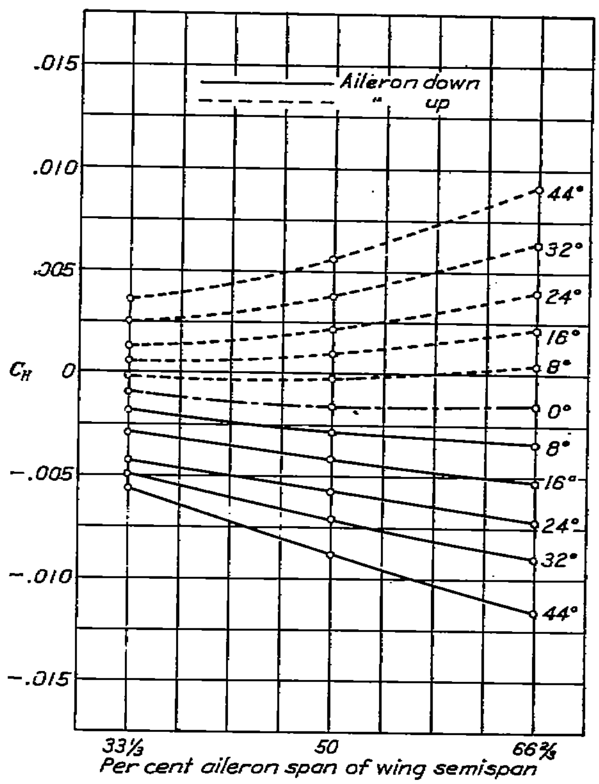

FIGURE 10.—Clark Y wing section. C_H for varying span—2.5-inch chord (25 per cent of wing chord). Pitch angle 0°. Roll angle 0°. Yaw angle 0°

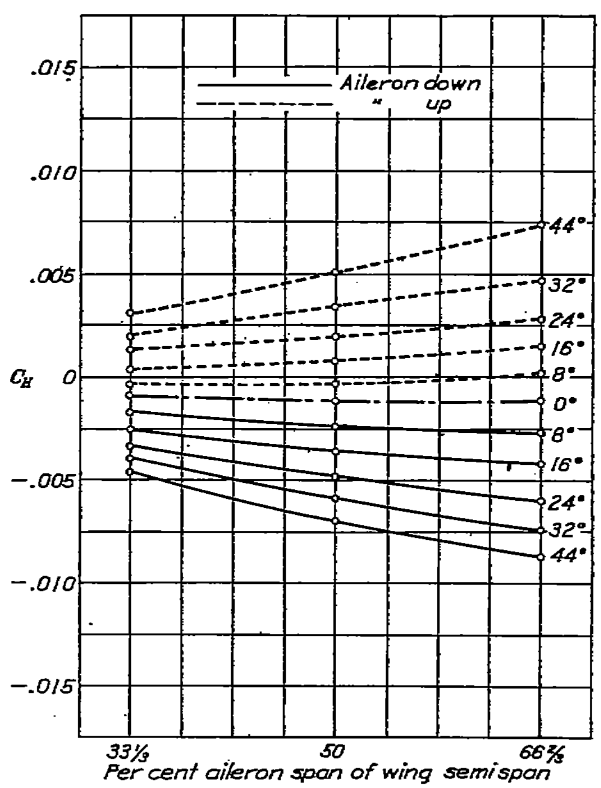

FIGURE 12.—U. S. A. 27 wing section. C_H for varying aileron span—2.5-inch chord (25 per cent of wing chord). Pitch angle 0°. Roll angle 0°. Yaw angle 0°

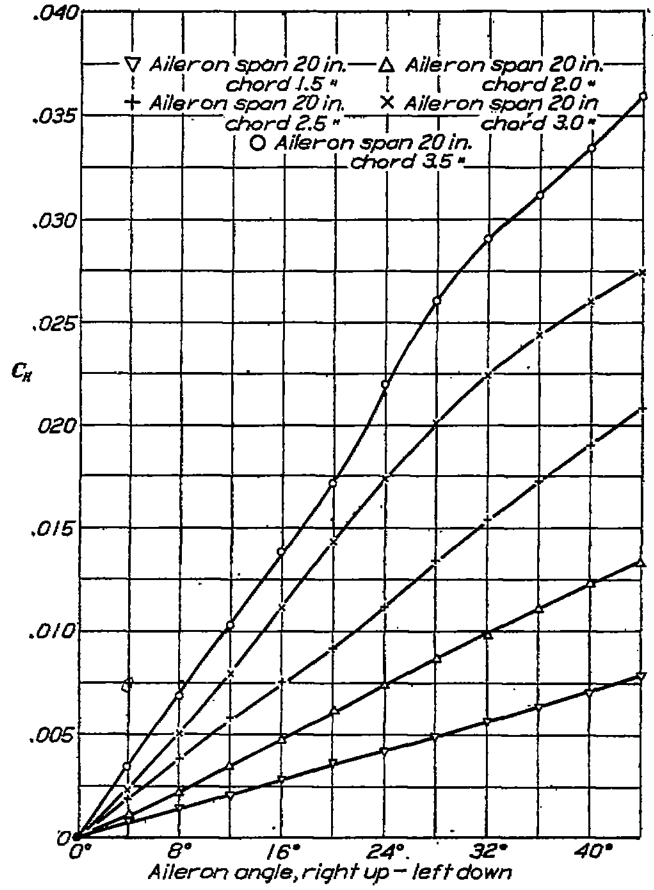

FIGURE 13.—Clark Y wing section. Combined C_H for varying aileron chord. Pitch angle 0°. Roll angle 0°. Yaw angle 0°

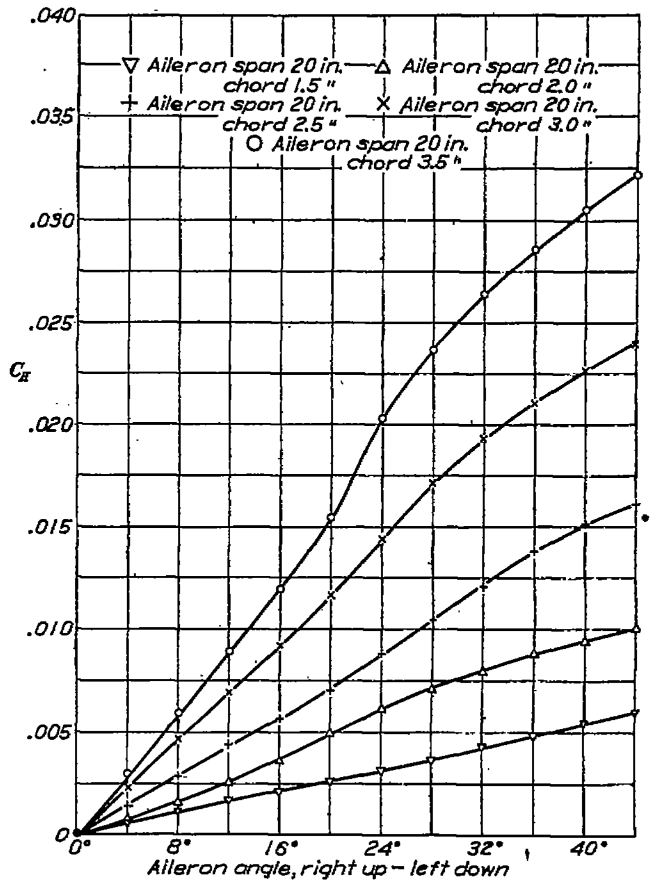

FIGURE 15.—U. S. A. 27 wing section. Combined C_H for varying aileron chord. Pitch angle 0°. Roll angle 0°. Yaw angle 0°

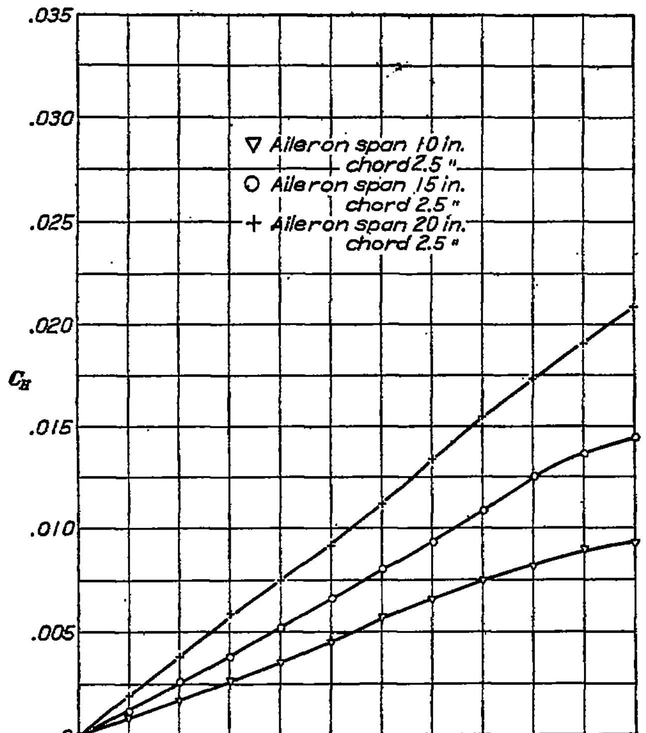

FIGURE 14.—Clark Y wing section. Combined C_H for varying aileron span. Pitch angle 0°. Roll angle 0°. Yaw angle 0°

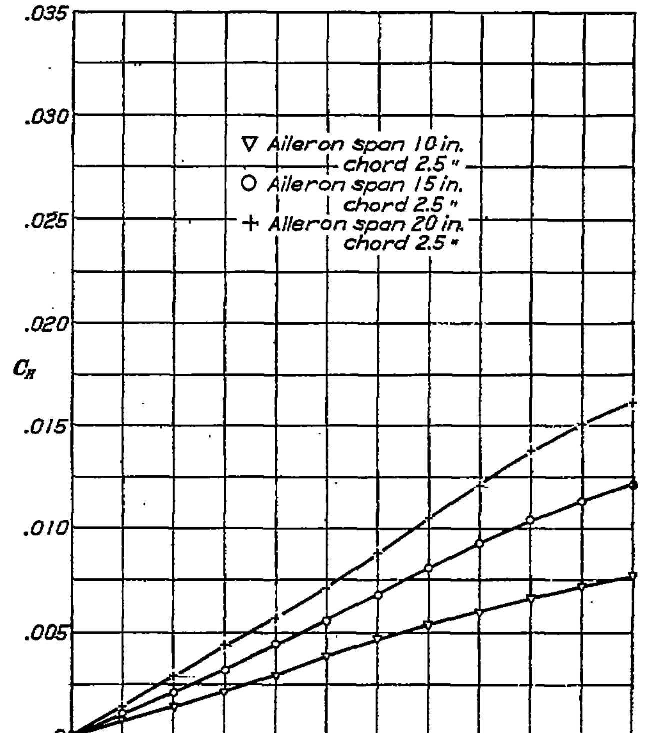

FIGURE 16.—U. S. A. 27 wing section. Combined C_H for varying aileron span. Pitch angle 0°. Roll angle 0°. Yaw angle 0°

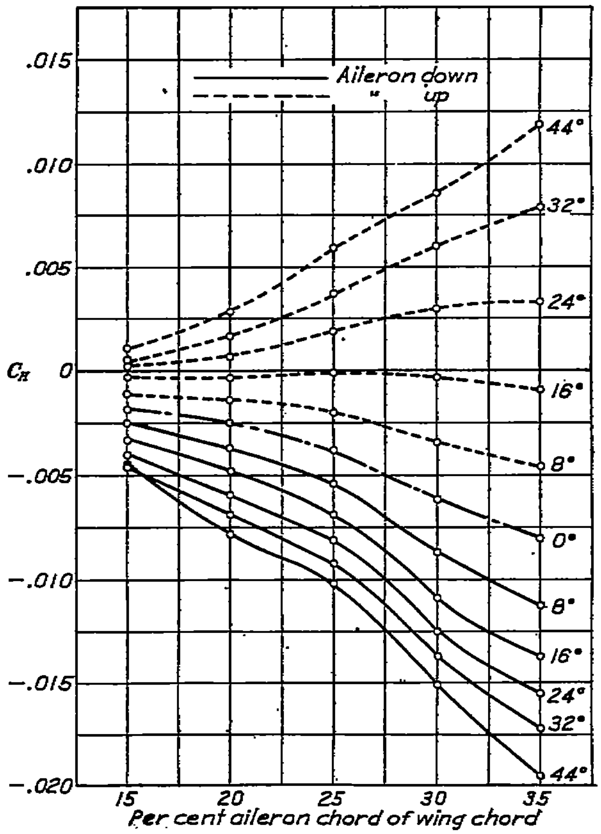

FIGURE 17.—Clark Y wing section. C_H for varying aileron chord—20-inch span (67 per cent of wing semispan). Pitch angle 12°. Roll angle 0°. Yaw angle 0°

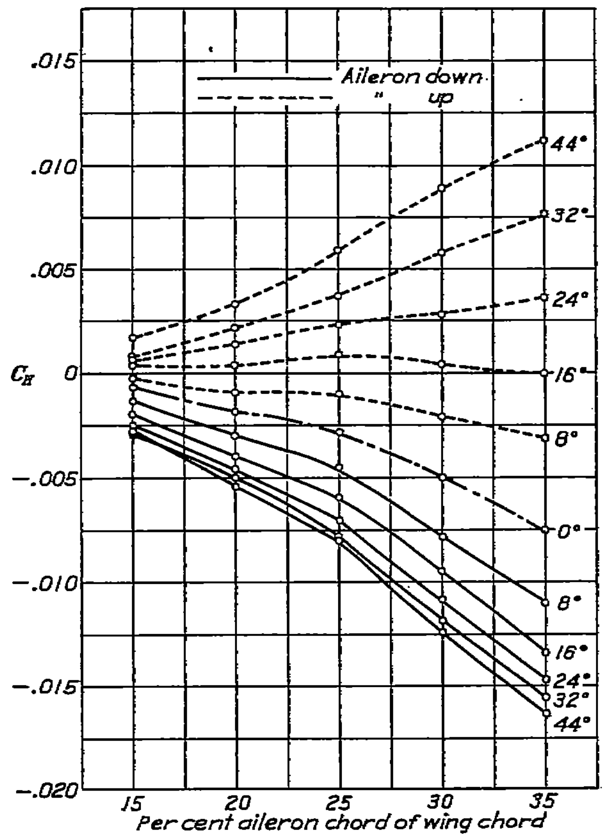

FIGURE 19.—U. S. A. 27 wing section. C_H for varying aileron chord—20-inch span (67 per cent of wing semispan). Pitch angle 12°. Roll angle 0°. Yaw angle 0°

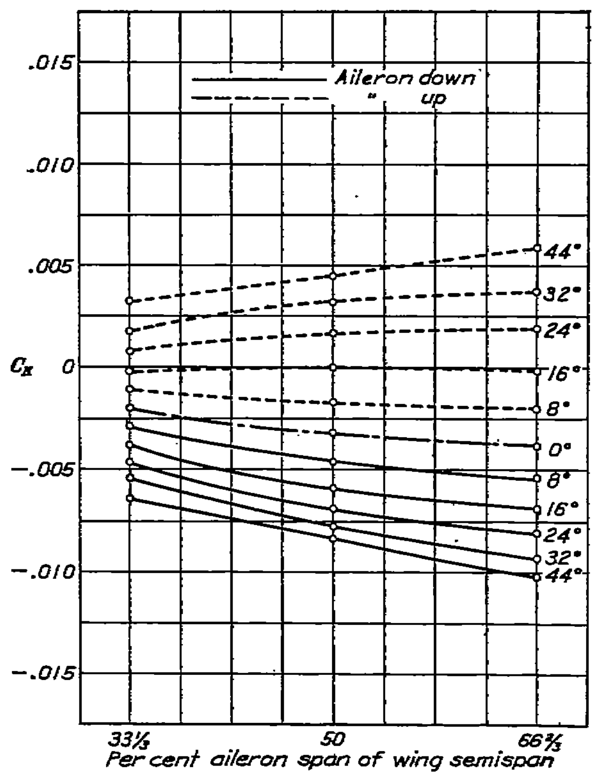

FIGURE 18.—Clark Y wing section. C_H for varying aileron span—2.5-inch chord (25 per cent of wing chord). Pitch angle 12°. Roll angle 0°. Yaw angle 0°

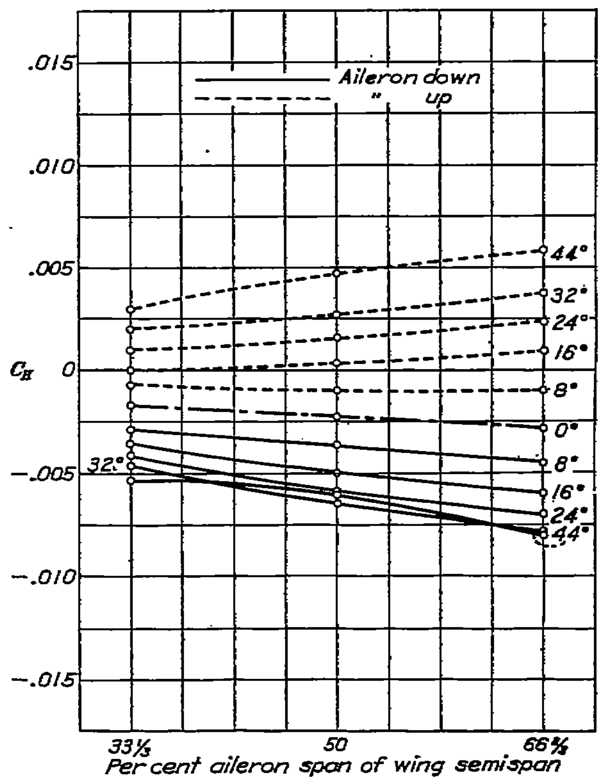

FIGURE 20.—U. S. A. 27 wing section. C_H for varying span aileron—2.5-inch chord (25 per cent of wing chord). Pitch angle 12°. Roll angle 0°. Yaw angle 0°

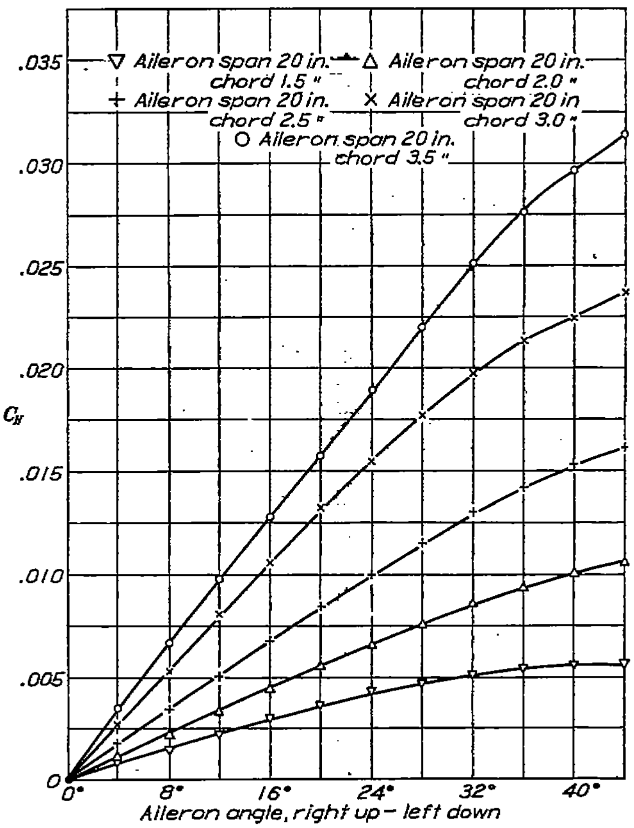

FIGURE 21.—Clark Y wing section. Combined C_H for varying aileron chord. Pitch angle 12°. Roll angle 0°. Yaw angle 0°

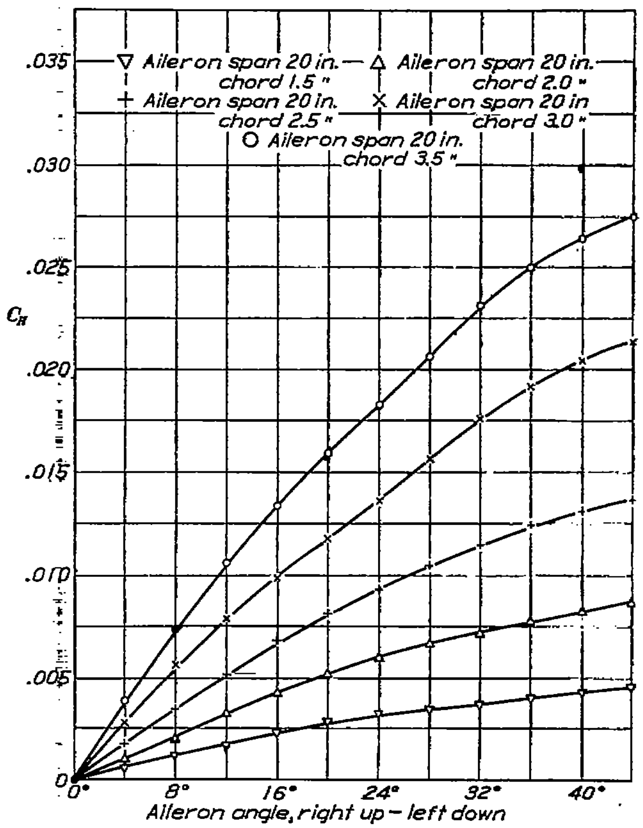

FIGURE 23.—U. S. A. 27 wing section. Combined C_H for varying aileron chord. Pitch angle 12°. Roll angle 0°. Yaw angle 0°

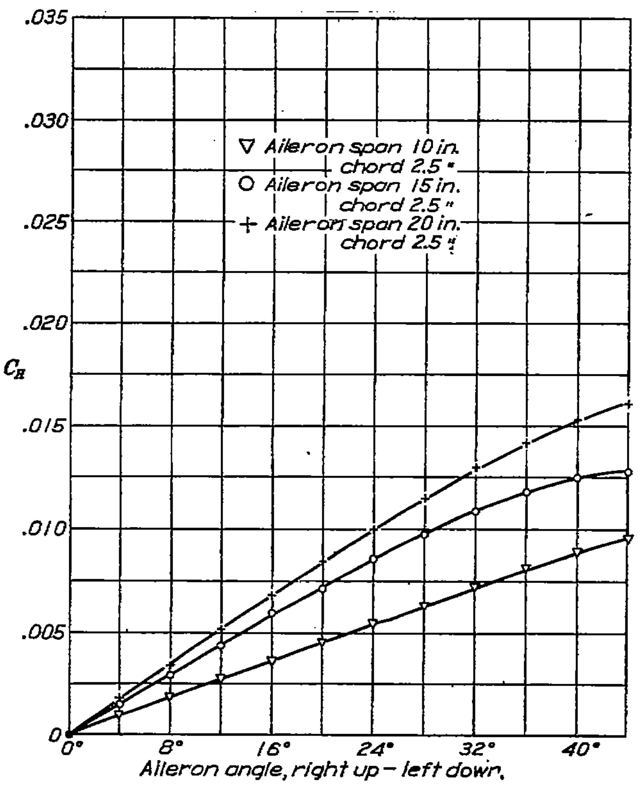

FIGURE 22.—Clark Y wing section. Combined C_H for varying aileron span. Pitch angle 12°. Roll angle 0°. Yaw angle 0°

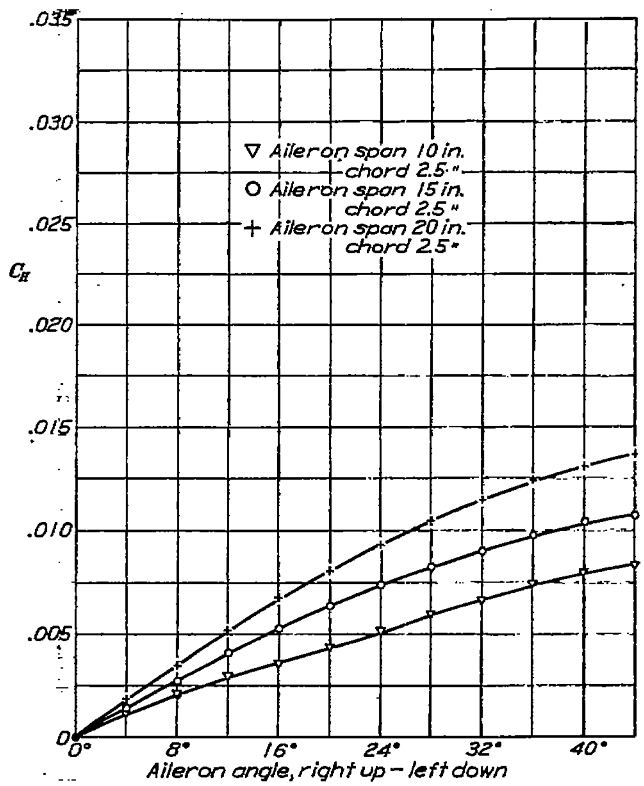

FIGURE 24.—U. S. A. 27 wing section. Combined C_H for varying aileron span. Pitch angle 12°. Roll angle 0°. Yaw angle 0°

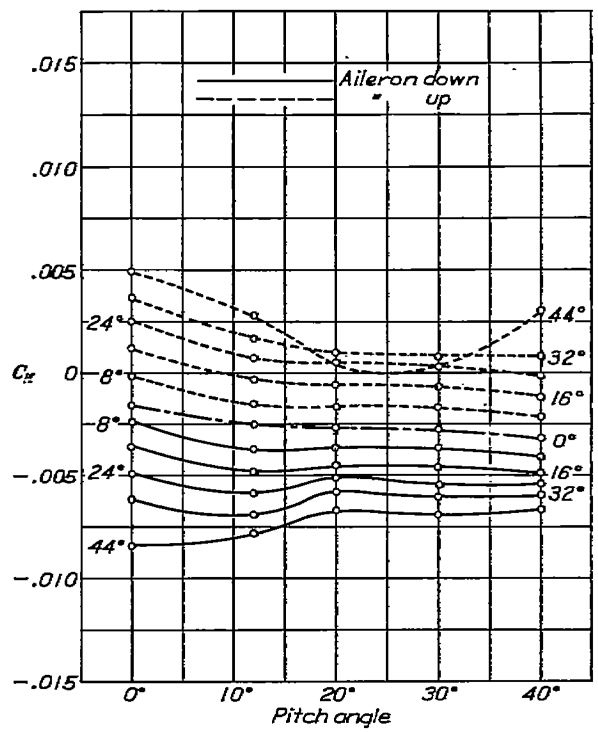

FIGURE 25.—Clark Y wing section. C_H versus pitch angle for one aileron. Aileron span 20 inches. Aileron chord 2.0 inches. Roll angle 0°. Yaw angle 0°

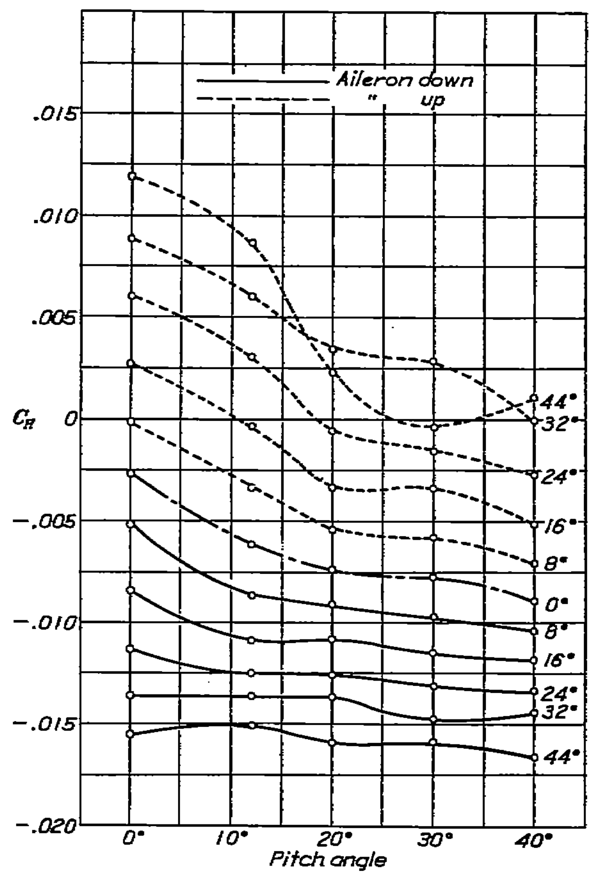

FIGURE 26.—Clark Y wing section. C_H versus pitch angle for one aileron. Aileron span 20 inches. Aileron chord 3.0 inches. Roll angle 0°. Yaw angle 0°

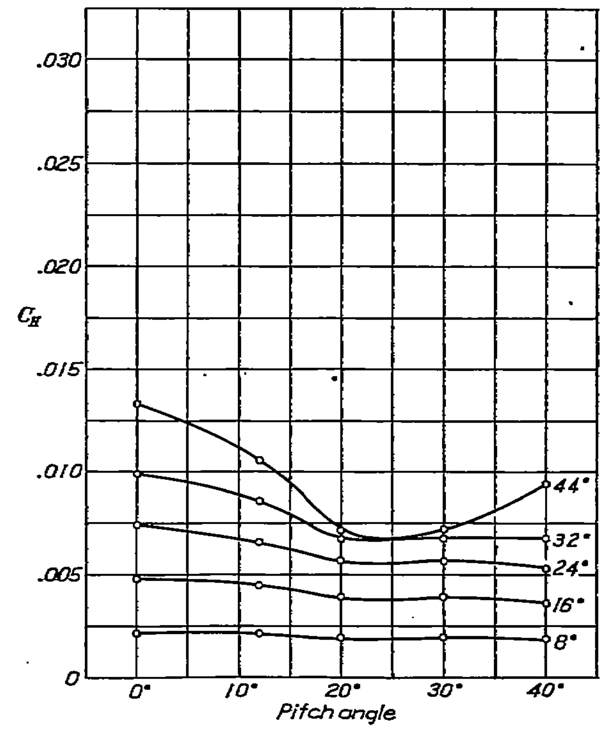

FIGURE 27.—Clark Y wing section. Combined C_H versus pitch angle for one aileron. Aileron span 20 inches. Aileron chord 2.0 inches. Roll angle 0°. Yaw angle 0°

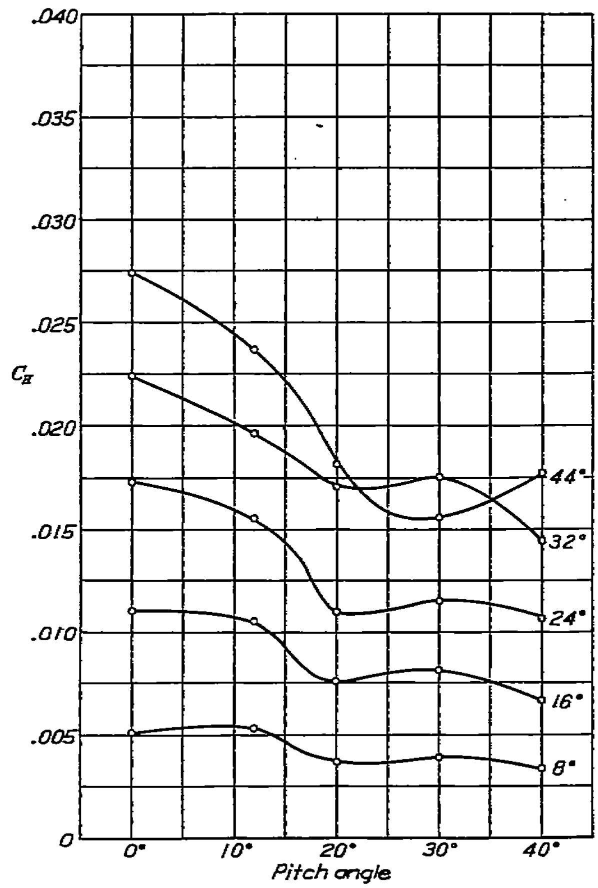

FIGURE 28.—Clark Y wing section. Combined C_H versus pitch angle for one aileron. Aileron span 20 inches. Aileron chord 3.0 inches. Roll angle 0°. Yaw angle 0°

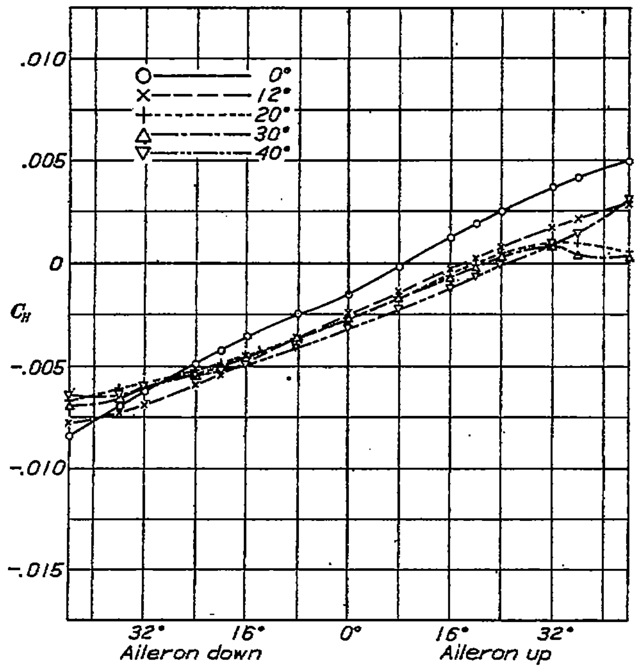

FIGURE 29.—Clark Y wing section. C_H versus aileron angle for various pitch angles. Aileron span 20 inches. Aileron chord 2.0 inches. Angle of roll 0°. Angle of yaw 0°

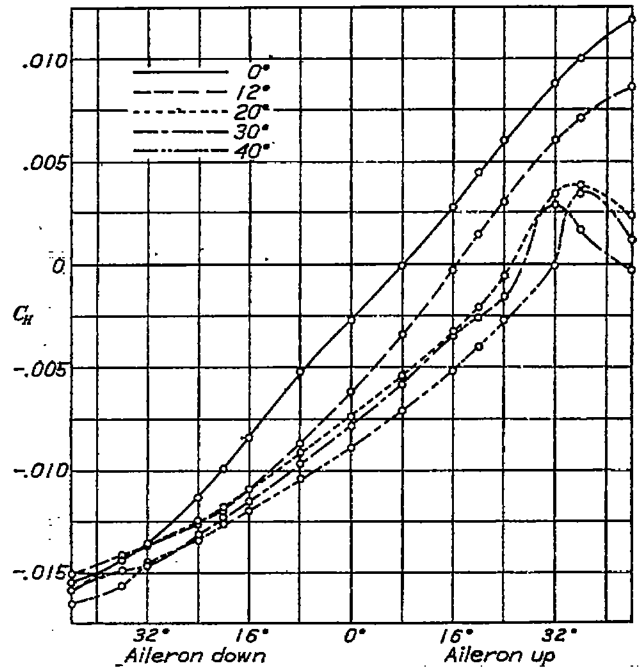

FIGURE 30.—Clark Y wing section. C_H versus aileron angle for various pitch angles. Aileron span 20 inches. Aileron chord 3.0 inches. Angle of roll 0°. Angle of yaw 0°

TABLE I.—CLARK Y WING SECTION—HINGE MOMENT COEFFICIENT

[Varying chord of aileron. Angle of pitch of airplane, 0°; angle of attack of wing, +4°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron; the signs refer to the right aileron]

AILERON SPAN 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 1.5 inches (15 per cent of wing chord)				Aileron chord 2 inches (20 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0007	−0.0007	0	0°	−0.0016	−0.0016	0
4°	−.0003	−.0011	+0.0008	4°	−.0008	−.0020	+0.0012
8°	0	−.0014	.0014	8°	−.0002	−.0024	.0022
12°	+.0003	−.0018	.0021	12°	+.0005	−.0030	.0035
16°	.0006	−.0022	.0028	16°	.0012	−.0036	.0048
20°	.0010	−.0026	.0036	20°	.0019	−.0043	.0062
24°	.0013	−.0029	.0042	24°	.0025	−.0049	.0074
28°	.0016	−.0033	.0049	28°	.0031	−.0056	.0087
32°	.0019	−.0037	.0056	32°	.0036	−.0062	.0098
36°	.0022	−.0041	.0063	36°	.0041	−.0070	.0111
40°	.0024	−.0046	.0070	40°	.0046	−.0077	.0123
44°	.0026	−.0052	.0078	44°	.0049	−.0084	.0133

Aileron chord 3 inches (30 per cent of wing chord)				Aileron chord 3.5 inches (35 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0027	−0.0027	0	0°	−0.0040	−0.0040	0
4°	−.0014	−.0039	+0.0025	4°	−.0022	−.0057	+0.0035
8°	−.0001	−.0052	.0051	8°	−.0006	−.0075	.0069
12°	+.0012	−.0067	.0079	12°	+.0011	−.0092	.0103
16°	.0027	−.0084	.0111	16°	.0027	−.0111	.0138
20°	.0044	−.0099	.0143	20°	.0014	−.0128	.0172
24°	.0060	−.0113	.0173	24°	.0077	−.0143	.0220
28°	.0075	−.0125	.0200	28°	.0104	−.0157	.0261
32°	.0088	−.0136	.0224	32°	.0121	−.0170	.0291
36°	.0100	−.0144	.0244	36°	.0130	−.0182	.0312
40°	.0110	−.0150	.0260	40°	.0140	−.0194	.0334
44°	.0119	−.0155	.0274	44°	.0153	−.0206	.0359

TABLE II.—CLARK Y WING SECTION—HINGE MOMENT COEFFICIENT

[Varying span of aileron. Angle of pitch of airplane, 0°; angle of attack of wing, +4°; angle of yaw, 0°, angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron; the signs refer to the right aileron]

AILERON CHORD 2.5 INCHES (25 PER CENT OF WING CHORD)

Aileron span 10 inches (33 per cent of wing semispan)				Aileron span 15 inches (50 per cent of wing semispan)			
	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0009	−0.0009	0	0°	−0.0016	−0.0016	0
4°	−.0005	−.0013	+0.0008	4°	−.0010	−.0022	+0.0012
8°	−.0001	−.0018	.0017	8°	−.0002	−.0028	.0026
12°	+.0003	−.0023	.0026	12°	+.0004	−.0034	.0038
16°	.0006	−.0029	.0035	16°	.0010	−.0042	.0052
20°	.0009	−.0036	.0045	20°	.0015	−.0050	.0065
24°	.0013	−.0043	.0056	24°	.0022	−.0058	.0080
28°	.0019	−.0046	.0065	28°	.0030	−.0064	.0094
32°	.0025	−.0049	.0074	32°	.0038	−.0071	.0109
36°	.0030	−.0051	.0081	36°	.0048	−.0077	.0125
40°	.0034	−.0054	.0088	40°	.0053	−.0083	.0136
44°	.0036	−.0056	.0092	44°	.0056	−.0088	.0144

Aileron span 20 inches (67 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values
0°	−0.0015	−0.0015	0
4°	−.0005	−.0024	+0.0019
8°	+.0004	−.0034	.0038
12°	.0014	−.0044	.0058
16°	.0022	−.0053	.0075
20°	.0029	−.0062	.0091
24°	.0040	−.0072	.0112
28°	.0053	−.0081	.0134
32°	.0064	−.0090	.0154
36°	.0074	−.0099	.0173
40°	.0083	−.0107	.0190
44°	.0092	−.0116	.0208

TABLE III.—U. S. A. 27 WING SECTION—HINGE MOMENT COEFFICIENT

[Varying chord of aileron. Angle of pitch of airplane, 0°; angle of attack of wing, +4°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON SPAN 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 1.5 inches (15 per cent of wing chord)				Aileron chord 2 inches (20 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0002	−0.0002	0	0°	−0.0009	−0.0009	0
4°	+.0002	−.0004	+0.0006	4°	−.0005	−.0012	+0.0007
8°	.0005	−.0006	.0011	8°	0	−.0017	.0017
12°	.0007	−.0010	.0017	12°	+.0005	−.0021	.0026
16°	.0008	−.0013	.0021	16°	.0010	−.0027	.0037
20°	.0010	−.0016	.0026	20°	.0017	−.0033	.0050
24°	.0012	−.0019	.0031	24°	.0023	−.0039	.0062
28°	.0015	−.0022	.0037	28°	.0029	−.0043	.0072
32°	.0018	−.0025	.0043	32°	.0034	−.0046	.0080
36°	.0021	−.0027	.0048	36°	.0039	−.0049	.0088
40°	.0025	−.0029	.0054	40°	.0043	−.0052	.0095
44°	.0028	−.0031	.0059	44°	.0045	−.0056	.0101

Aileron chord 3 inches (30 per cent of wing chord)				Aileron chord 3.5 inches (35 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0028	−0.0028	0	0°	−0.0040	−0.0040	0
4°	−.0016	−.0039	+0.0023	4°	−.0025	−.0055	+0.0030
8°	−.0004	−.0051	.0047	8°	−.0012	−.0072	.0060
12°	+.0007	−.0062	.0069	12°	0	−.0089	.0089
16°	.0018	−.0074	.0092	16°	+.0015	−.0105	.0120
20°	.0030	−.0086	.0116	20°	.0034	−.0120	.0154
24°	.0046	−.0098	.0144	24°	.0069	−.0134	.0203
28°	.0062	−.0109	.0171	28°	.0091	−.0146	.0237
32°	.0074	−.0119	.0193	32°	.0106	−.0158	.0264
36°	.0085	−.0125	.0210	36°	.0119	−.0169	.0288
40°	.0095	−.0131	.0226	40°	.0130	−.0177	.0307
44°	.0104	−.0135	.0239	44°	.0141	−.0182	.0323

TABLE IV.—U. S. A. 27 WING SECTION—HINGE MOMENT COEFFICIENT

[Varying span of aileron. Angle of pitch of airplane, 0°; angle of attack of wing, +4°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON CHORD 2.5 INCHES (25 PER CENT OF WING CHORD)

Aileron span 10 inches (33 per cent of wing semispan)				Aileron span 15 inches (50 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0009	−0.0009	0	0°	−0.0012	−0.0012	0
4°	−.0006	−.0013	+0.0007	4°	−.0007	−.0018	+0.0011
8°	−.0003	−.0017	.0014	8°	−.0003	−.0024	.0021
12°	0	−.0021	.0021	12°	+.0002	−.0030	.0032
16°	+.0004	−.0025	.0029	16°	.0008	−.0036	.0044
20°	.0009	−.0029	.0038	20°	.0013	−.0042	.0055
24°	.0014	−.0033	.0047	24°	.0020	−.0048	.0068
28°	.0017	−.0036	.0053	28°	.0027	−.0054	.0081
32°	.0020	−.0039	.0059	32°	.0034	−.0059	.0093
36°	.0024	−.0042	.0066	36°	.0040	−.0064	.0104
40°	.0028	−.0044	.0072	40°	.0046	−.0067	.0113
44°	.0031	−.0046	.0077	44°	.0051	−.0070	.0121

Aileron span 20 inches (67 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values
0°	−0.0012	−0.0012	0
4°	−.0005	−.0019	+0.0014
8°	+.0002	−.0027	.0029
12°	.0009	−.0035	.0044
16°	.0015	−.0042	.0057
20°	.0021	−.0050	.0071
24°	.0028	−.0060	.0088
28°	.0037	−.0068	.0105
32°	.0047	−.0074	.0121
36°	.0058	−.0080	.0138
40°	.0067	−.0084	.0151
44°	.0074	−.0087	.0161

TABLE V.—CLARK Y WING SECTION—HINGE MOMENT COEFFICIENT

[Varying chord of aileron. Angle of pitch of airplane, +12°; angle of attack of wing, +16°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON SPAN 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 1.5 inches (15 per cent of wing chord)				Aileron chord 2 inches (20 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0018	−0.0018	0	0°	−0.0025	−0.0025	0
4°	−.0014	−.0022	+0.0008	4°	−.0020	−.0031	+0.0011
8°	−.0011	−.0025	.0014	8°	−.0014	−.0037	.0023
12°	−.0007	−.0029	.0022	12°	−.0009	−.0042	.0033
16°	−.0003	−.0033	.0030	16°	−.0003	−.0048	.0045
20°	0	−.0036	.0036	20°	+.0002	−.0054	.0056
24°	+.0003	−.0040	.0043	24°	.0007	−.0059	.0066
28°	.0004	−.0043	.0047	28°	.0012	−.0064	.0076
32°	.0005	−.0046	.0051	32°	.0017	−.0069	.0086
36°	.0007	−.0047	.0054	36°	.0021	−.0073	.0094
40°	.0008	−.0048	.0056	40°	.0025	−.0076	.0101
44°	.0011	−.0045	.0056	44°	.0028	−.0078	.0106

Aileron chord 3 inches (30 per cent of wing chord)				Aileron chord 3.5 inches (35 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0062	−0.0062	0	0°	−0.0080	−0.0080	0
4°	−.0048	−.0075	+0.0027	4°	−.0063	−.0098	+0.0035
8°	−.0034	−.0087	.0053	8°	−.0046	−.0113	.0067
12°	−.0018	−.0099	.0081	12°	−.0028	−.0126	.0098
16°	−.0003	−.0109	.0106	16°	−.0009	−.0137	.0128
20°	+.0014	−.0118	.0132	20°	+.0011	−.0146	.0157
24°	.0030	−.0125	.0155	24°	.0033	−.0155	.0188
28°	.0046	−.0131	.0177	28°	.0056	−.0164	.0220
32°	.0060	−.0137	.0197	32°	.0079	−.0172	.0251
36°	.0071	−.0142	.0213	36°	.0096	−.0180	.0276
40°	.0079	−.0147	.0226	40°	.0109	−.0188	.0297
44°	.0086	−.0151	.0237	44°	.0119	−.0195	.0314

TABLE VI.—CLARK Y WING SECTION—HINGE MOMENT COEFFICIENT

Varying span of aileron. Angle of pitch of airplane, +12°; angle of attack of wing, +16°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON CHORD, 2.5 INCHES (25 PER CENT OF WING CHORD)

Aileron span 10 inches (33 per cent of wing semispan)				Aileron span 15 inches (50 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0020	−0.0020	0	0°	−0.0032	−0.0032	0
4°	−.0015	−.0024	+0.0009	4°	−.0025	−.0040	+0.0015
8°	−.0011	−.0029	.0018	8°	−.0017	−.0046	.0029
12°	−.0006	−.0033	.0027	12°	−.0009	−.0053	.0044
16°	−.0002	−.0038	.0036	16°	0	−.0059	.0059
20°	+.0003	−.0042	.0045	20°	+.0008	−.0064	.0072
24°	.0008	−.0046	.0054	24°	.0017	−.0069	.0086
28°	.0013	−.0050	.0063	28°	.0024	−.0074	.0098
32°	.0018	−.0054	.0072	32°	.0032	−.0077	.0109
36°	.0022	−.0059	.0081	36°	.0037	−.0081	.0118
40°	.0027	−.0062	.0089	40°	.0042	−.0083	.0125
44°	.0032	−.0064	.0096	44°	.0045	−.0083	.0128

Aileron span 20 inches (67 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values
0°	−0.0038	−0.0038	0
4°	−.0029	−.0046	+0.0017
8°	−.0020	−.0054	.0034
12°	−.0011	−.0062	.0051
16°	−.0001	−.0069	.0068
20°	+.0009	−.0076	.0085
24°	.0019	−.0081	.0100
28°	.0028	−.0087	.0115
32°	.0037	−.0092	.0129
36°	.0045	−.0097	.0142
40°	.0052	−.0101	.0153
44°	.0059	−.0102	.0161

TABLE VII.—U. S. A. 27 WING SECTION—HINGE MOMENT COEFFICIENT

[Varying chord of aileron. Angle of pitch of airplane, +12°; angle of attack of wing, +16°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON SPAN, 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 1.5 inches (15 per cent of wing chord)				Aileron chord 2 inches (20 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0007	−0.0007	0	0°	−0.0018	−0.0018	0
4°	−.0004	−.0010	+0.0006	4°	−.0013	−.0024	+0.0011
8°	−.0002	−.0013	.0011	8°	−.0009	−.0030	.0021
12°	+.0001	−.0016	.0017	12°	−.0002	−.0035	.0033
16°	.0004	−.0019	.0023	16°	+.0004	−.0039	.0043
20°	.0006	−.0022	.0028	20°	.0009	−.0043	.0052
24°	.0007	−.0025	.0032	24°	.0014	−.0016	.0060
28°	.0007	−.0027	.0034	28°	.0018	−.0049	.0067
32°	.0008	−.0029	.0037	32°	.0022	−.0050	.0072
36°	.0010	−.0030	.0040	36°	.0026	−.0052	.0078
40°	.0013	−.0030	.0043	40°	.0030	−.0053	.0083
44°	.0017	−.0028	.0015	44°	.0033	−.0054	.0087

Aileron chord 3 inches (30 per cent of wing chord)				Aileron chord 3.5 inches (35 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0050	−0.0050	0	0°	−0.0075	−0.0075	0
4°	−.0035	−.0066	+0.0031	4°	−.0055	−.0094	+0.0039
8°	−.0021	−.0078	.0057	8°	−.0036	−.0110	.0074
12°	−.0008	−.0087	.0079	12°	−.0017	−.0124	.0107
16°	+.0004	−.0095	.0099	16°	0	−.0134	.0134
20°	.0016	−.0102	.0118	20°	+.0018	−.0141	.0159
24°	.0028	−.0108	.0136	24°	.0036	−.0147	.0183
28°	.0043	−.0114	.0157	28°	.0056	−.0151	.0207
32°	.0058	−.0118	.0176	32°	.0077	−.0155	.0232
36°	.0071	−.0121	.0192	36°	.0092	−.0158	.0250
40°	.0081	−.0123	.0204	40°	.0104	−.0160	.0264
44°	.0089	−.0124	.0213	44°	.0112	−.0163	.0275

TABLE VIII.—U. S. A. 27 WING SECTION—HINGE MOMENT COEFFICIENT

[Varying span of aileron. Angle of pitch of airplane, +12°; angle of attack of wing +16°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON CHORD 2.5 INCHES (25 PER CENT OF WING CHORD)

Aileron span 10 inches (33 per cent of wing semispan)				Aileron span 15 inches (50 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0017	−0.0017	0	0°	−0.0023	−0.0023	0
4°	−.0012	−.0023	+.0011	4°	−.0016	−.0030	+.0014
8°	−.0007	−.0028	.0021	8°	−.0010	−.0037	.0027
12°	−.0003	−.0032	.0029	12°	−.0003	−.0044	.0041
16°	0	−.0035	.0035	16°	+.0003	−.0050	.0053
20°	+.0005	−.0038	.0043	20°	.0009	−.0055	.0064
24°	.0010	−.0041	.0051	24°	.0015	−.0059	.0074
28°	.0015	−.0044	.0059	28°	.0021	−.0062	.0083
32°	.0020	−.0046	.0066	32°	.0027	−.0064	.0091
36°	.0025	−.0049	.0074	36°	.0033	−.0005	.0098
40°	.0028	−.0051	.0079	40°	.0040	−.0004	.0104
44°	.0030	−.0053	.0083	44°	.0047	−.0000	.0107

Aileron span 20 inches (67 per cent of wing semispan)			
θ	Aileron up	Aileron down	Combined values
0°	−0.0028	−0.0028	0
4°	−.0019	−.0037	+.0018
8°	−.0010	−.0045	.0035
12°	0	−.0052	.0052
16°	+.0009	−.0059	.0068
20°	.0016	−.0065	.0081
24°	.0023	−.0070	.0093
28°	.0030	−.0075	.0105
32°	.0037	−.0078	.0115
36°	.0044	−.0080	.0124
40°	.0051	−.0080	.0131
44°	.0058	−.0079	.0137

TABLE IX.—CLARK Y WING SECTION—HINGE MOMENT COEFFICIENT

[Varying chord of aileron. Angle of pitch of airplane, +20°; angle of attack of wing, +24°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON SPAN 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 2 inches (20 per cent of wing chord)				Aileron chord 3 inches (30 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0027	−0.0027	0	0°	−0.0074	−0.0074	0
4°	−.0022	−.0032	+.0010	4°	−.0064	−.0082	+.0018
8°	−.0017	−.0037	.0020	8°	−.0054	−.0091	.0037
12°	−.0012	−.0041	.0029	12°	−.0044	−.0099	.0055
16°	−.0006	−.0045	.0039	16°	−.0033	−.0109	.0076
20°	−.0001	−.0048	.0047	20°	−.0021	−.0120	.0099
24°	+.0005	−.0052	.0057	24°	−.0006	−.0126	.0120
28°	.0009	−.0055	.0064	28°	+.0014	−.0131	.0147
32°	.0010	−.0058	.0068	32°	.0034	−.0137	.0171
36°	.0009	−.0061	.0070	36°	.0038	−.0144	.0182
40°	.0008	−.0064	.0072	40°	.0032	−.0151	.0183
44°	.0005	−.0067	.0072	44°	.0023	−.0159	.0182

[Varying chord of aileron. Angle of pitch of airplane, +30°; angle of attack of wing, +34°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON SPAN 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 2 inches (20 per cent of wing chord)				Aileron chord 3 inches (30 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0027	−0.0027	0	0°	−0.0078	−0.0078	0
4°	−.0022	−.0032	+.0010	4°	−.0068	−.0088	+.0020
8°	−.0017	−.0037	.0020	8°	−.0058	−.0097	.0039
12°	−.0012	−.0042	.0030	12°	−.0046	−.0106	.0060
16°	−.0007	−.0046	.0039	16°	−.0034	−.0115	.0081
20°	−.0002	−.0050	.0048	20°	−.0026	−.0123	.0097
24°	+.0003	−.0054	.0057	24°	−.0016	−.0132	.0116
28°	.0007	−.0057	.0064	28°	+.0012	−.0140	.0152
32°	.0008	−.0060	.0068	32°	.0028	−.0147	.0175
36°	.0003	−.0063	.0066	36°	.0016	−.0149	.0165
40°	.0002	−.0066	.0068	40°	.0005	−.0153	.0158
44°	.0003	−.0069	.0072	44°	−.0003	−.0159	.0156

TABLE IX.—CLARK Y WING SECTION—HINGE MOMENT COEFFICIENT—Continued

[Varying chord of aileron. Angle of pitch of airplane, +40°; angle of attack of wing, +44°; angle of yaw, 0°; angle of roll, 0°]

[NOTE.—The values apply to either right or left aileron, the signs refer to the right aileron]

AILERON SPAN 20 INCHES (67 PER CENT OF WING SEMISPAN)

Aileron chord 2 inches (20 per cent of wing chord)				Aileron chord 3 inches (30 per cent of wing chord)			
θ	Aileron up	Aileron down	Combined values	θ	Aileron up	Aileron down	Combined values
0°	−0.0032	−0.0032	0	0°	−0.0089	−0.0089	0
4°	−.0027	−.0037	+.0010	4°	−.0080	−.0097	+.0017
8°	−.0022	−.0041	.0019	8°	−.0071	−.0104	.0033
12°	−.0017	−.0046	.0029	12°	−.0062	−.0112	.0050
16°	−.0012	−.0049	.0037	16°	−.0052	−.0119	.0067
20°	−.0007	−.0056	.0049	20°	−.0040	−.0126	.0086
24°	−.0001	−.0054	.0053	24°	−.0027	−.0134	.0107
28°	+.0003	−.0055	.0058	28°	−.0016	−.0138	.0122
32°	.0008	−.0060	.0068	32°	−.0001	−.0145	.0144
36°	.0014	−.0064	.0078	36°	+.0034	−.0157	.0191
40°	.0022	−.0064	.0086	40°	.0026	−.0163	.0189
44°	.0030	−.0064	.0094	44°	.0011	−.0166	.0177

LETTER OF SUBMITTAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D. C., October 9, 1930.

GENTLEMEN: The chairman of the committee on problems of air navigation in a letter dated October 24, 1928, to the subcommittee on instruments, requested that at the outset the subcommittee prepare and submit a report summing up the present status of air navigation instruments, and include in the report the specific recommendations of the subcommittee. In response to this request the subcommittee has prepared a report on the Present Status of Aircraft Instruments, a copy of which is attached hereto.

In preparing this report it was believed inadvisable to limit the scope to a consideration of the class of instruments ordinarily called navigation instruments, because the safe operation of an aircraft may depend as well upon the satisfactory performance of other aircraft instruments. Accordingly the scope of the report was enlarged to include the present state of development of aircraft instruments. The customary classification of instruments is followed in the report, which contains sections on speed, altitude, navigation, power plant, oxygen, and fog-flying instruments. The recommendations of the subcommittee are embodied in the sections on general problems and summary of instrument and research problems. The outstanding problems at the present time are those relating to navigation in fog and to landing during fog and poor visibility. A satisfactory solution of those problems will no doubt depend largely on the use and development of radio equipment and special instruments. The other research problems which are outlined in this report relate mainly to the refinement of existing instruments in order to secure greater accuracy and reliability, which may greatly increase safety during flight.

On behalf of the subcommittee on instruments I have the honor to recommend that the attached report be published as a Technical Report of the National Advisory Committee for Aeronautics.

Respectfully,

SUBCOMMITTEE ON INSTRUMENTS,
L. J. BRIGGS, *Chairman.*

THE EXECUTIVE COMMITTEE,
National Advisory Committee for Aeronautics, Washington, D. C.
(Through the committee on problems of air navigation.)

ORGANIZATION

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